

Ion injection from LEBT to RHIC EBIS

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Ion injection from the end of flat horizontal deflector at the entrance into LEBT to the entrance into drift tube #12 (last tube before the electron suppressor) was simulated with TRAK program. The layout of this part of EBIS is presented in Fig. 1.

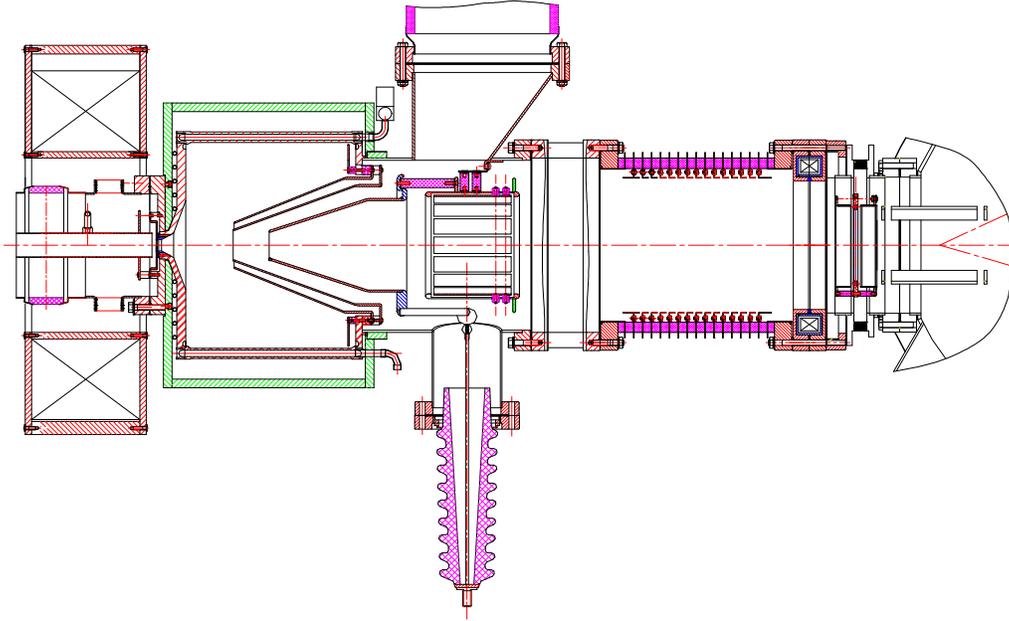


Fig. 1. RHIC EBIS region of simulations of ion injection.

For simulations was used Au^{1+} ion beam with currents 50.0 μA , 400.0 μA , and 1.0 mA and energies 14.0 keV and 21 keV. The electron current was 10.0 A and the potential of electron collector with respect to the cathode of electron gun was 10.0 kV. The number of electron trajectories was 300 and number of ion trajectories was 500.

The initial “portraits” of ion beam for currents are presented in Fig. 2 and Fig. 3.

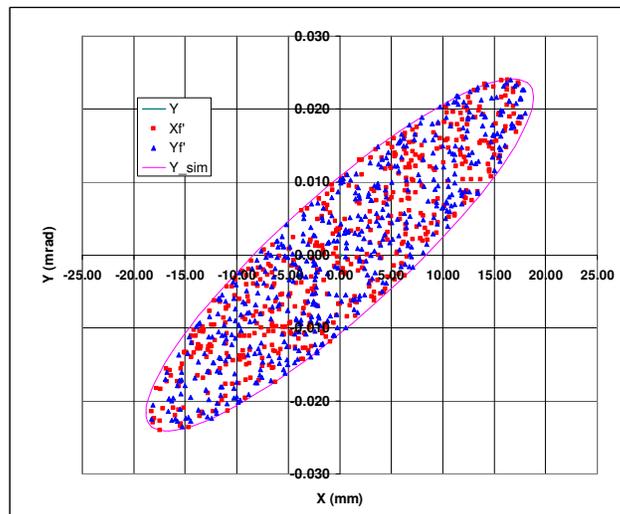


Fig. 2. Initial phase space of the ion beam used for 50.0 μA and 400.0 μA ion beams.
 $E_{\text{unnorm}}=202.3.4 \text{ mm} \cdot \text{mrad}$, $E_{\text{RMS_norm}}=0.0242 \text{ mm} \cdot \text{mrad}$

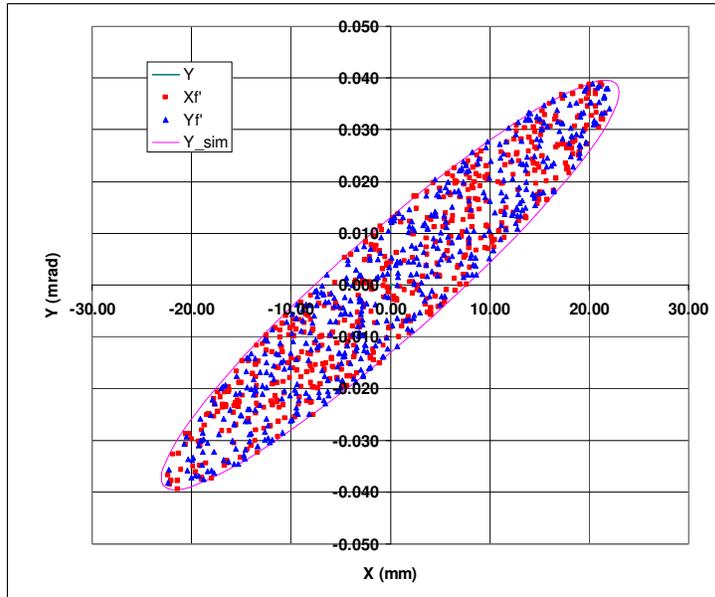


Fig. 3. Initial phase space of the ion beam used for 1.0 mA ion beam. $E_{\text{unnorm}}=303.4$ mm*mrad, $E_{\text{RMS_norm}}=0.0353$ mm*mrad

These simulations demonstrated that RHIC EBIS ion optics designed and optimized for ion extraction suits very well for ion injection as well. The flexibility of ion injection is achieved with combination of the positive adaptor and negative ion lens. By changing both voltages one can change the diameter and the converging angle at the entrance into EC aperture (much like optimizing injection into RFQ). It is expected that for higher injection efficiency one needs to inject ions in a smaller fraction of electron beam and with as small as possible angles. With only clear criteria of simulations on this stage – transmission without losses, efforts were made to minimize the diameter of ion beam and keep it at smallest possible entrance angle. Examples of the phase space “portraits” of the ion beam at the end of the problem for ultimate cases (50.0 μA 21.0 keV and 1.0 mA at 14.0 keV) are presented in Fig. 4 and Fig. 5.

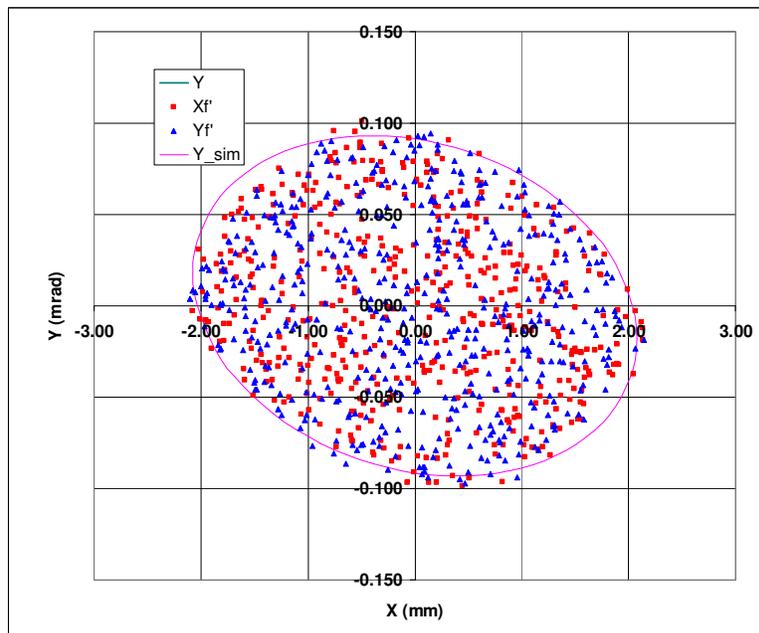


Fig. 4. Final phase space of ion beam with $I_{\text{ion}}=50.0$ μA , $E_{\text{ion}}=21.0$ keV.

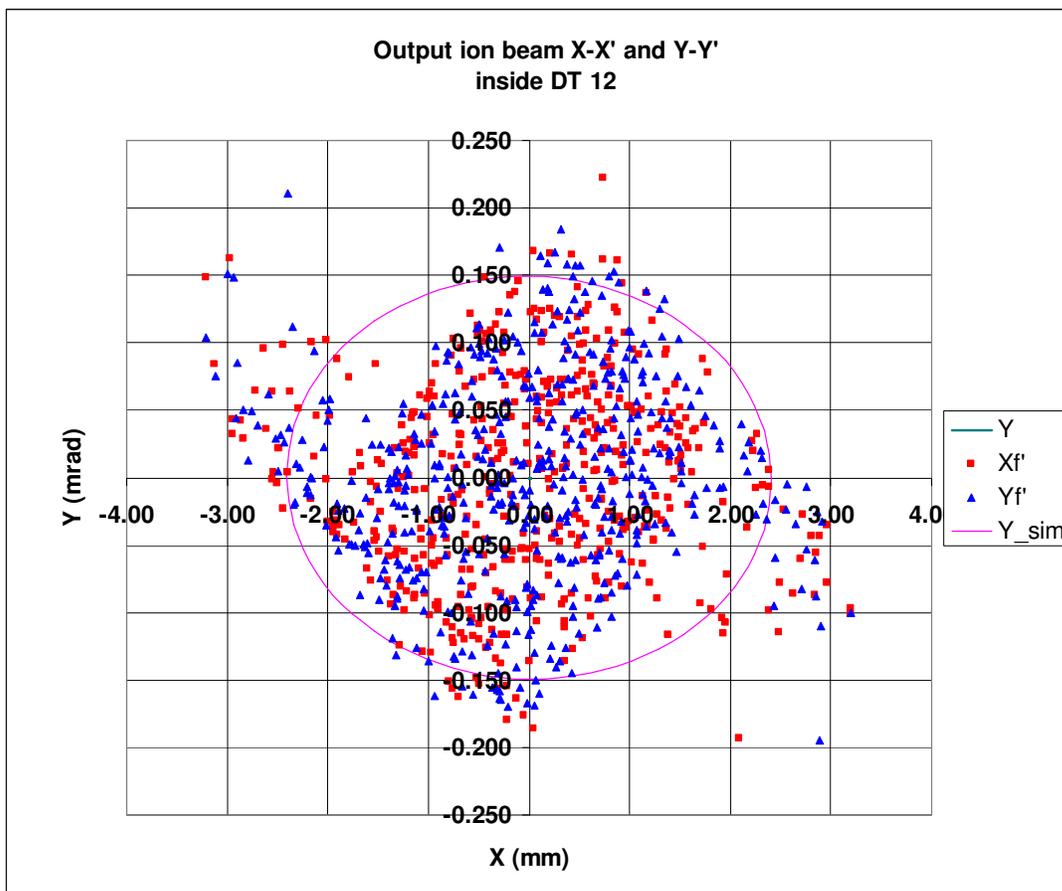


Fig. 5. Final phase space of ion beam with $I_{\text{ion}}=1.0$ mA, $E_{\text{ion}}=14.0$ keV.

The results of simulations are presented in Fig. 6-17.

Summary.

These simulations demonstrated:

1. The ion beam can be transported from the region before the gridded lens at the entrance into LEBT to the drift tube #12 without losses for all currents and energies used.
2. For currents $50.0 \mu\text{A}$ and $400.0 \mu\text{A}$ the ion beam can be injected inside a central part of electron beam with diameter less than 50% of the total electron beam diameter for energies 21 keV and 14 keV.
3. 1.0 mA ion beam has larger maximum diameter than $50.0 \mu\text{A}$ or $400.0 \mu\text{A}$ ion beams and this is a reason of aberrations in adaptor-ion lens interface. These aberrations result in boosting of its emittance and increasing of the ion beam diameter inside the electron beam. Nevertheless for the most part ion beam at the entrance into drift tube #12 is smaller than the electron beam and has a chance to be trapped.
4. Simulations of the ion injection into the trap model will be done shortly.

This Plot Created On: June 10, 2008
at 11:50:40

EOU File: 50MK21K32K18K2K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 50mk21kV32k18k2k2.TOU

$I_{el}=10.0$ A
 $U_{EC}=10.0$ kV
 $U_{refl}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr} = U_{cath}-7.0$ kV
 $U_{ion_lens} = -42.0$ kV
 $U_{adaptor} = +8.0$ kV
 $U_{grid} = -2.0$ kV

Au+1, $I_{ion}=50.0$ mA
 $E_{ion}=21.0$ keV
Emit_unnorm=202.0 mm*mrad
Emit_RMS_norm=0.024 mm*mrad
 $r_{init}= 18.0$ mm
Alfa= -2.0 Beta= 1.75
Divergence=24 mrad

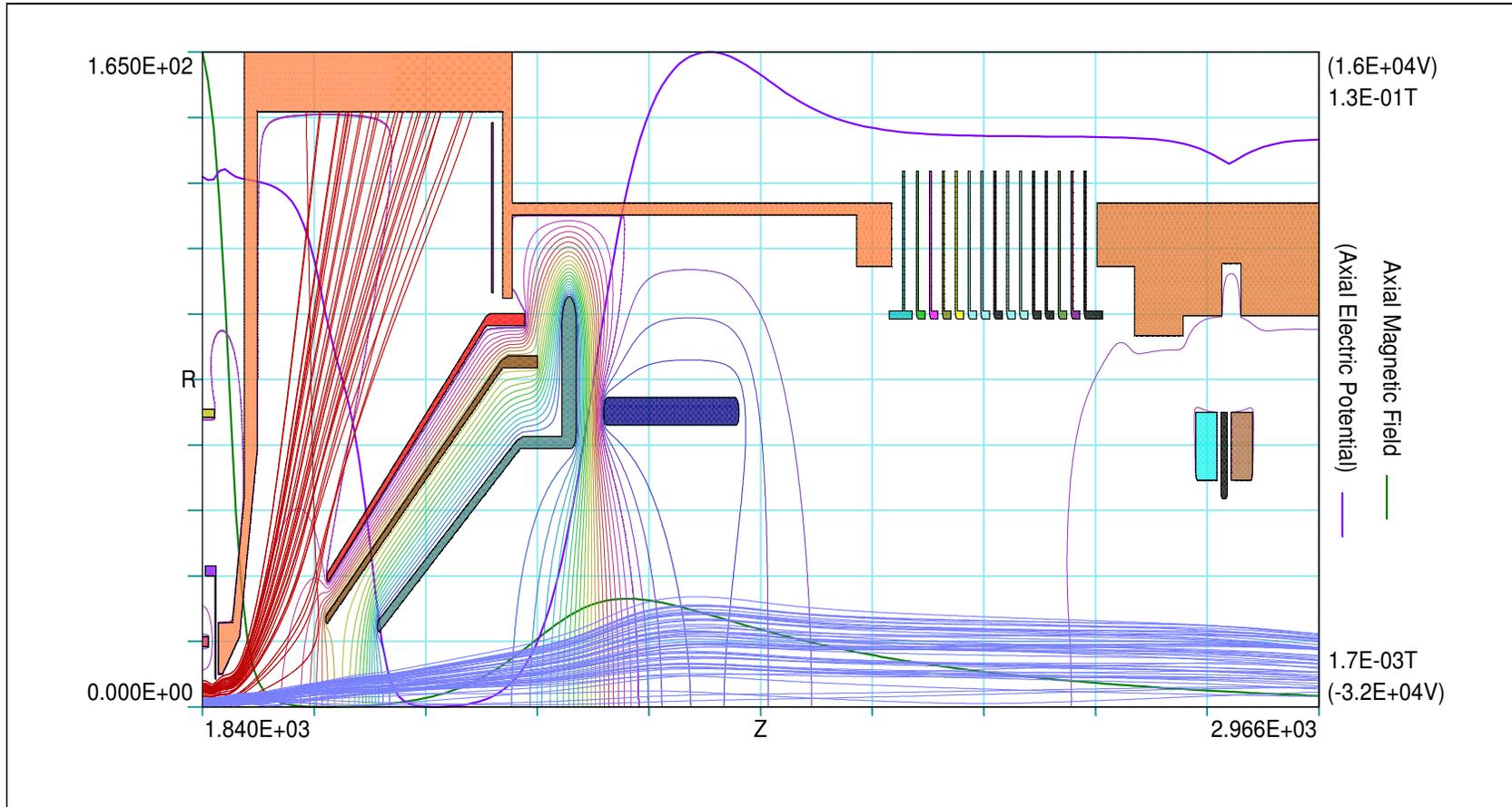


Fig. 6. $I_{ion}=50.0$ μ A, $E_{ion}=21.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad

This Plot Created On: June 10, 2008
at 11:50:40

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BOU File: M32_16_1_69E5.BOU
TOU File: 50mk21kV32k18k2k2.TOU

$I_{el}=10.0$ A
 $U_{EC}=10.0$ kV
 $U_{refl}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr} = U_{cath}-7.0$ kV
 $U_{ion_lens} = -42.0$ kV
 $U_{adaptor} = +8.0$ kV
 $U_{grid} = -2.0$ kV

Au+1, $I_{ion}=50.0$ mA
 $E_{ion}=21.0$ keV
Emit_unnorm=202.0 mm*mrad
Emit_RMS_norm=0.024 mm*mrad
 $r_{init}= 18.0$ mm
Alfa= -2.0 Beta= 1.75
Divergence=24 mrad

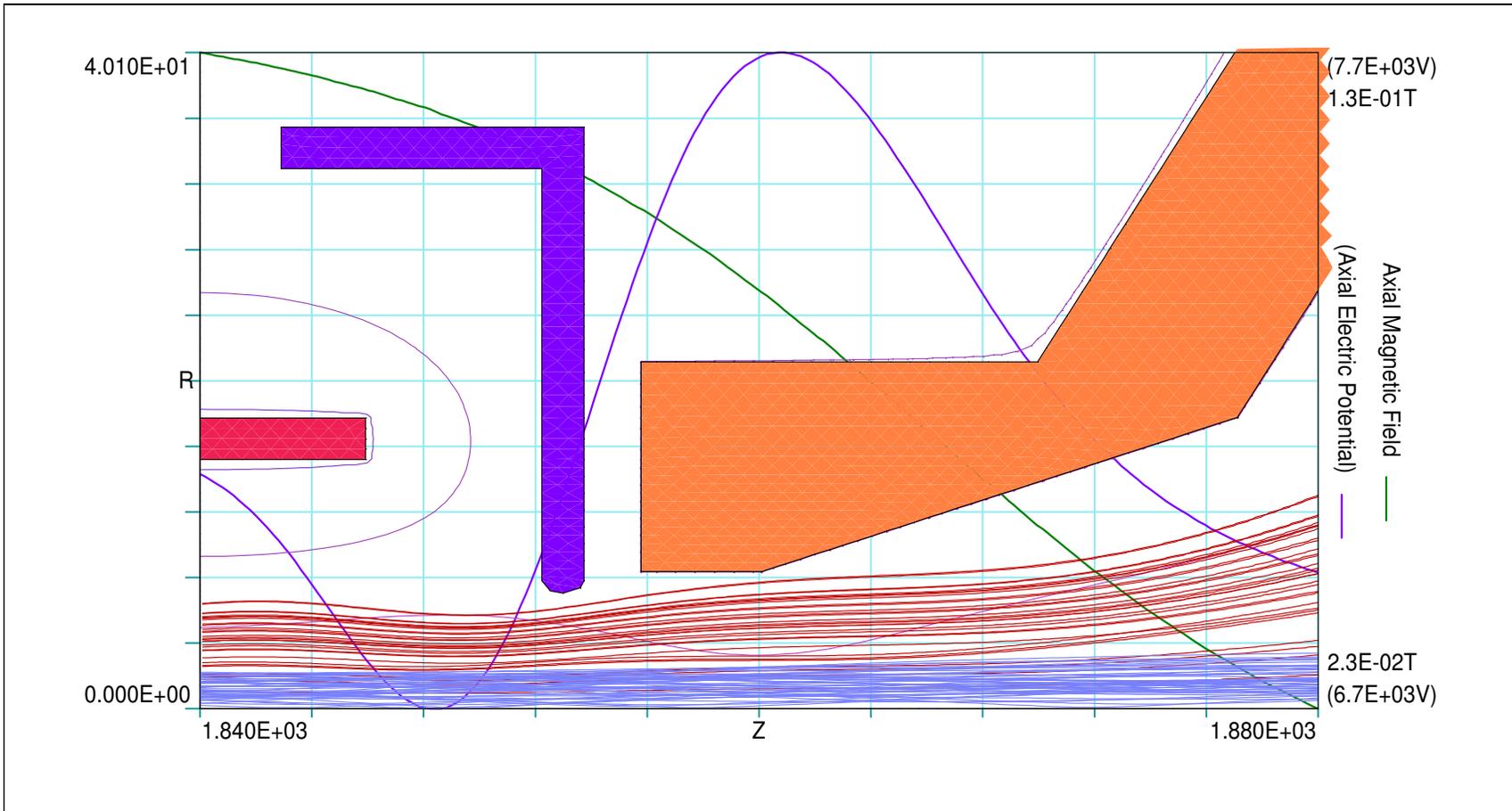


Fig. 7. $I_{ion}=50.0$ μ A, $E_{ion} =21.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad, Zoom at the EC entrance with the same X and Y scale.

This Plot Created On: June 11, 2008
at 11:16:23

EOU File: 400M21K34K19K3K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 400mk21keV34k19k3k.TOU

$I_{el} = 10.0$ A
 $U_{EC} = 10.0$ kV
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0$ kV
 $U_{ion_extr} = U_{cath} - 7.0$ kV
 $U_{ion_lens} = -44.0$ kV
 $U_{adaptor} = +9.0$ kV
 $U_{grid} = 3.0$ kV

Au1+, $I_{ion} = 400.0$ mA
 $E_{ion} = 21.0$ keV
 $Emit_unnorm = 202.0$ mm*mrad
 $Emit_RMS_norm = 0.024$ mm*mrad
 $R_{init} = 18$ mm
 $Divergence_init = 20$ mrad
 $Alfa_init = -2.0$, $Beta_init = 1.75$

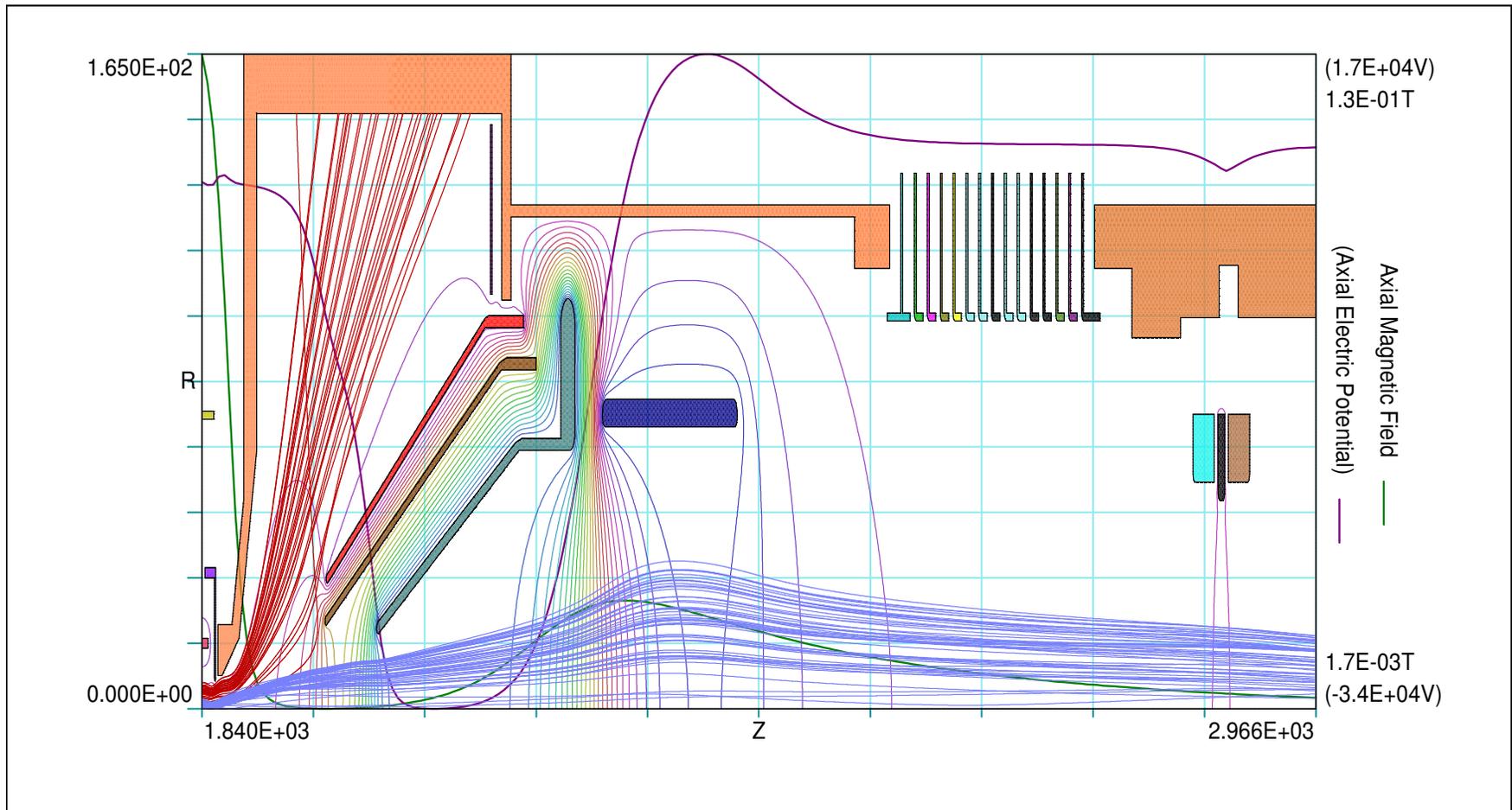


Fig. 8. $I_{ion} = 400.0$ μ A, $E_{ion} = 21.0$ keV, $\epsilon_{unnorm} = 202.3$ mm*mrad, $\epsilon_{RMS_norm} = 0.024$ mm*mrad.

This Plot Created On: June 11, 2008
at 11:16:23

EOU File: 400M21K34K19K3K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 400mk21keV34k19k3k.TOU

$I_{el} = 10.0 \text{ A}$
 $U_{EC} = 10.0 \text{ kV}$
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0 \text{ kV}$
 $U_{ion_extr} = U_{cath} - 7.0 \text{ kV}$
 $U_{ion_lens} = -44.0 \text{ kV}$
 $U_{adaptor} = +9.0 \text{ kV}$
 $U_{grid} = 3.0 \text{ kV}$

Au1+, $I_{ion} = 400.0 \text{ mA}$
 $E_{ion} = 21.0 \text{ keV}$
 $Emit_unnorm = 202.0 \text{ mm} \cdot \text{mrad}$
 $Emit_RMS_norm = 0.024 \text{ mm} \cdot \text{mrad}$
 $R_{init} = 18 \text{ mm}$
 $Divergence_{init} = 20 \text{ mrad}$
 $Alfa_{init} = -2.0, \text{Beta}_{init} = 1.75$

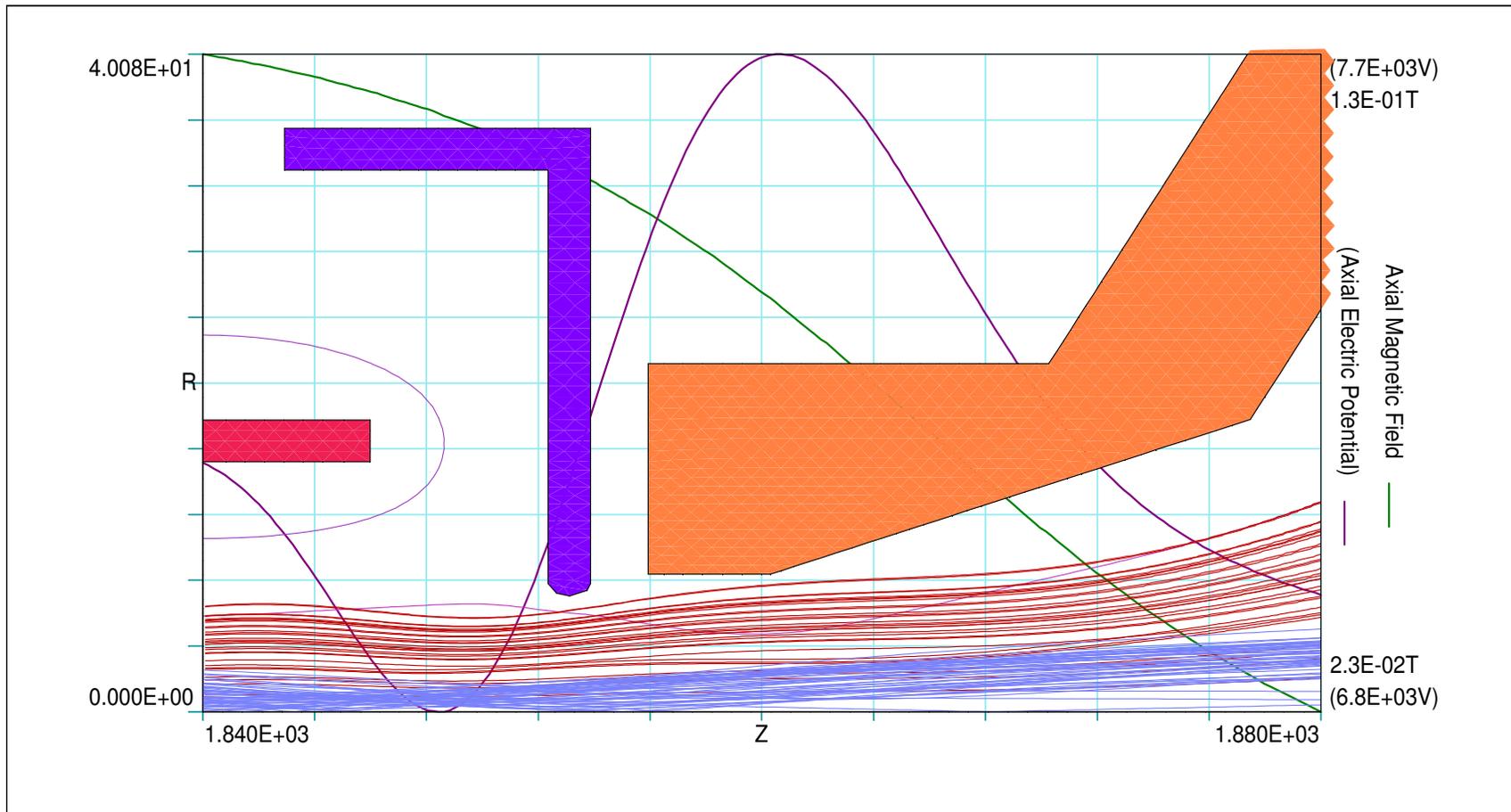


Fig. 9. $I_{ion} = 400.0 \text{ } \mu\text{A}$, $E_{ion} = 21.0 \text{ keV}$, $\epsilon_{unnorm} = 202.3 \text{ mm} \cdot \text{mrad}$, $\epsilon_{RMS_norm} = 0.024 \text{ mm} \cdot \text{mrad}$, Zoom at the EC entrance with the same X and Y scale.

This Plot Created On: June 9, 2008
at 11: 6: 4

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BOU File: M32_16_1_69E5.BOU
TOU File: 50mk14kV25k14k2k2.TOU

$I_{el}=10.0$ A
 $U_{EC}=10.0$ kV
 $U_{ref}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr} = U_{cath}-7.0$ kV
 $U_{ion_lens} = -35.0$ kV
 $U_{adaptor} = +4.0$ kV
 $U_{grid} = -2.0$ kV

Au+1, $I_{ion}=50.0$ mA
 $E_{ion}=14.0$ keV
Emit_unnorm=202.0 mm*mrad
Emit_RMS_norm=0.024 mm*mrad
 $r_{init}= 18.0$ mm
Alfa= -2.0 Beta= 1.75
Divergence=24 mrad

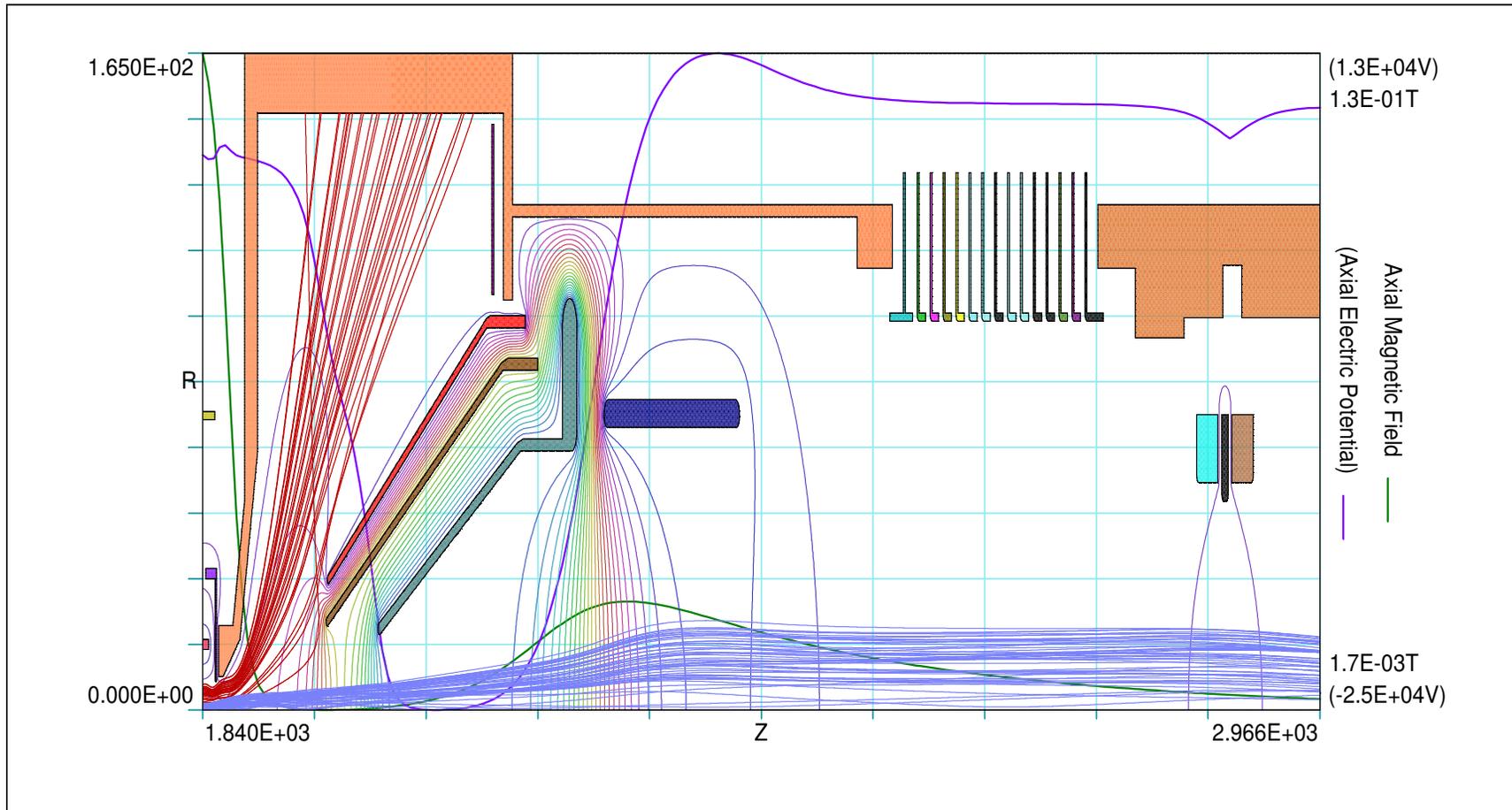


Fig. 10. $I_{ion}=50.0$ μ A, $E_{ion}=14.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad.

This Plot Created On: June 9, 2008
at 11: 6: 4

EOU File: F50M14K25K14K2K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 50mk14kV25k14k2k2.TOU

$I_{el}=10.0$ A
 $U_{EC}=10.0$ kV
 $U_{refl}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr} = U_{cath}-7.0$ kV
 $U_{ion_lens} = -35.0$ kV
 $U_{adaptor} = +4.0$ kV
 $U_{grid} = -2.0$ kV

Au+1, $I_{ion}=50.0$ mA
 $E_{ion}=14.0$ keV
 $Emit_unnorm=202.0$ mm*mrad
 $Emit_RMS_norm=0.024$ mm*mrad
 $r_{init}= 18.0$ mm
Alfa= -2.0 Beta= 1.75
Divergence=24 mrad

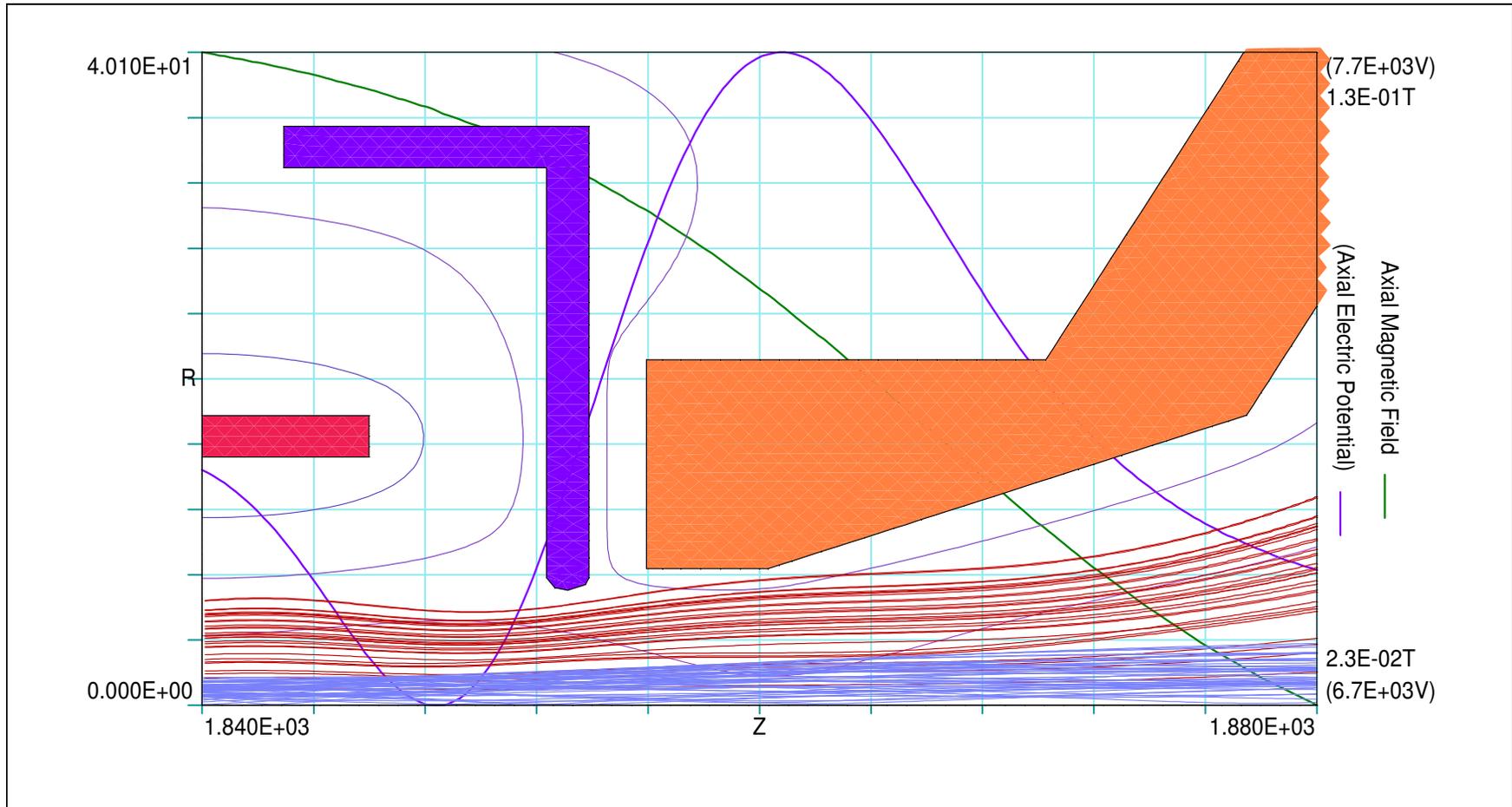


Fig. 11. $I_{ion}=50.0$ μ A, $E_{ion}=14.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad, Zoom at the EC entrance with the same X and Y scale.

This Plot Created On: June 9, 2008
at 10: 7:30

EOU File: 400M14K33K17K4K.EO
BOU File: M32_16_1_69E5.BOU
TOU File: 400mk14kV33k17k4k2.T

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 $U_{EC}=10.0$ kV
 $U_{refl}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr}=U_{cath}-7.0$ kV
 $U_{ion_lens}=-43.0$ kV
 $U_{adaptor}=+7.0$ kV
 $U_{grid}=-4.0$ kV

Au+1, $I_{ion}=400.0$ mA
 $E_{ion}=14.0$ keV
Emit_unnorm=202.0 mm*mrad
Emit_RMS_norm=0.024 mm*mrad
 $r_{init}=18.0$ mm
Alfa= -2.0 Beta= 1.75
Divergence=24 mrad

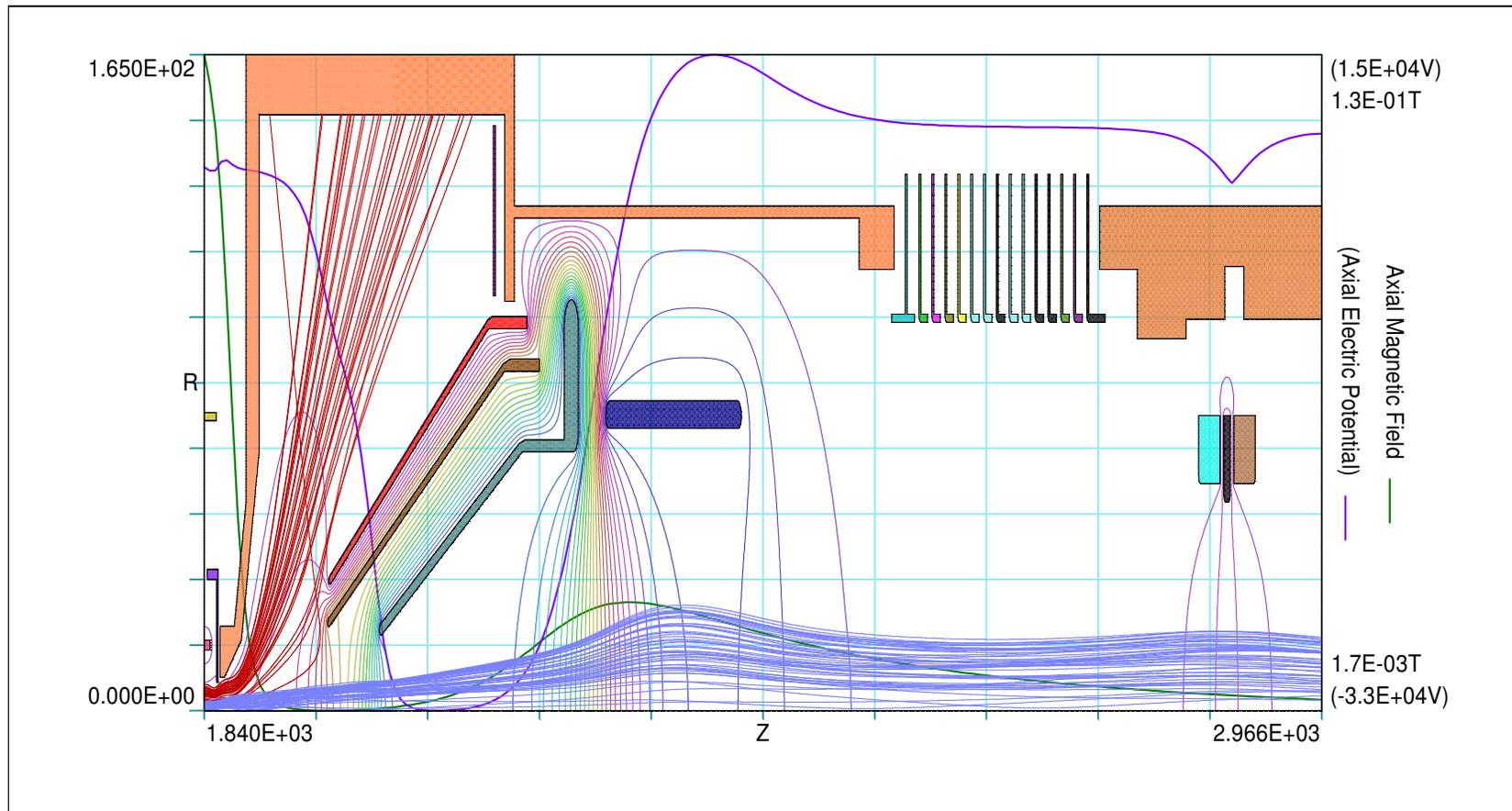


Fig. 12. $I_{ion}=400.0$ μ A, $E_{ion}=14.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad.

This Plot Created On: June 9, 2008
at 10: 7:30

EOU File: 400M14K33K17K4K.EO
BOU File: M32_16_1_69E5.BOU
TOU File: 400mk14kV33k17k4k2.T

$I_{el}=10.0$ A
 $U_{EC}=10.0$ kV
 $U_{refl}=U_{EC}$
 $U_{repel}=U_{EC}+1.0$ kV
 $U_{ion_extr}=U_{cath}-7.0$ kV
 $U_{ion_lens}=-43.0$ kV
 $U_{adaptor}=+7.0$ kV
 $U_{grid}=-4.0$ kV

Au+1, $I_{ion}=400.0$ mA
 $E_{ion}=14.0$ keV
 $Emit_unnorm=202.0$ mm*mrad
 $Emit_RMS_norm=0.024$ mm*mrad
 $r_{init}=18.0$ mm
 $Alfa=-2.0$ $Beta=1.75$
Divergence=24 mrad

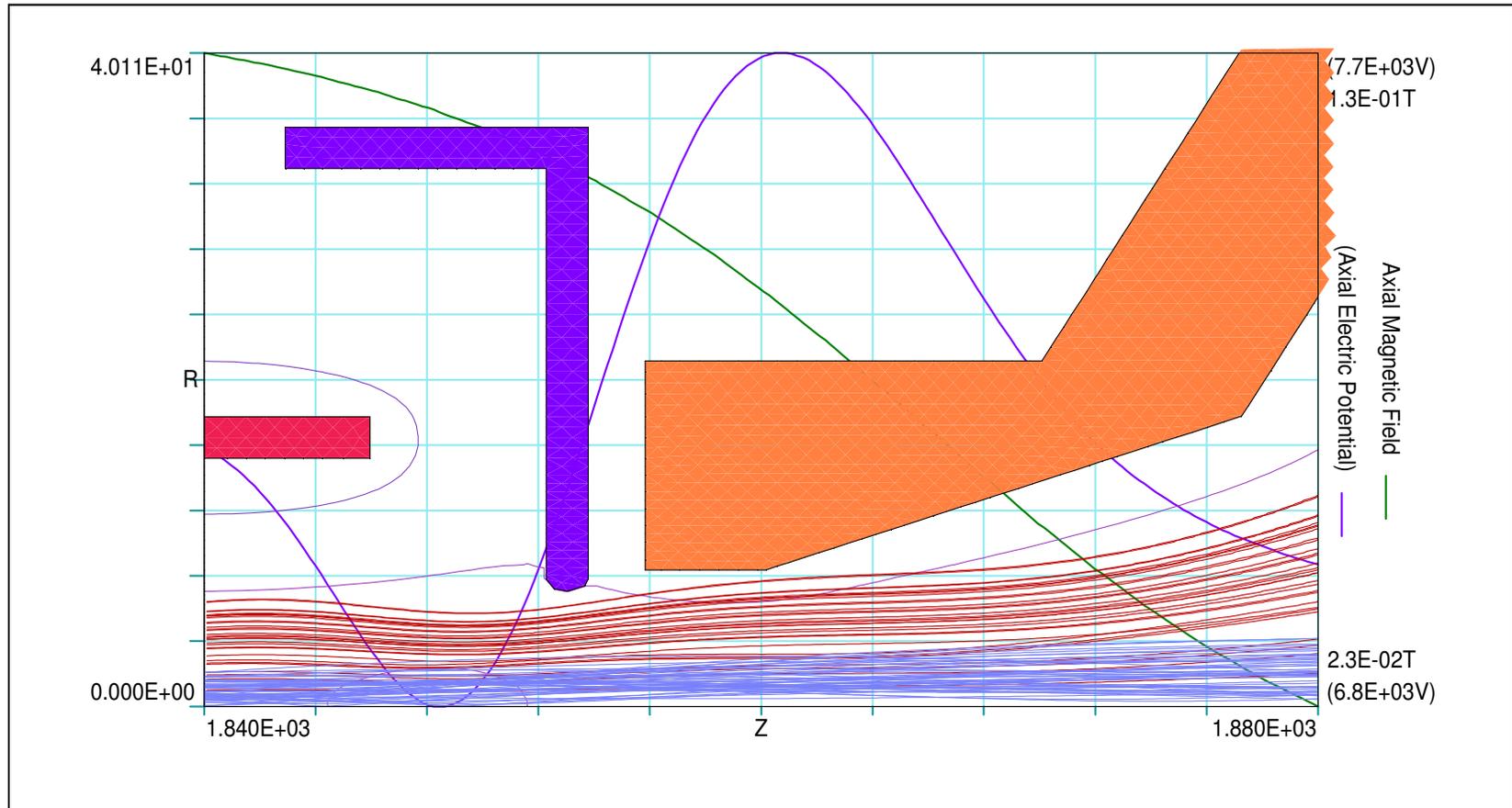


Fig. 13. $I_{ion}=400.0$ μ A, $E_{ion}=14.0$ keV, $\epsilon_{unnorm}=202.3$ mm*mrad, $\epsilon_{RMS_norm}=0.024$ mm*mrad, Zoom at the EC entrance with the same X and Y scale.

This Plot Created On: June 11, 2008
at 11:35:28

EOU File: 1mA21K40K18K3K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 1mA21keV40k18k3k.TOU

$I_{el} = 10.0 \text{ A}$
 $U_{EC} = 10.0 \text{ kV}$
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0 \text{ kV}$
 $U_{ion_extr} = U_{cath} - 7.0 \text{ kV}$
 $U_{ion_lens} = -50.0 \text{ kV}$
 $U_{adaptor} = +8.0 \text{ kV}$
 $U_{grid} = -3.0 \text{ kV}$

Au1+, $I_{ion} = 1.0 \text{ mA}$
 $E_{ion} = 21.0 \text{ keV}$
 $Emit_unnorm = 303.0 \text{ mm} \cdot \text{mrad}$
 $Emit_RMS_norm = 0.036 \text{ mm} \cdot \text{mrad}$
 $R_{init} = 24 \text{ mm}$
 $Divergence_init = 40 \text{ mrad}$
 $Alfa_init = -2.8, \text{Beta_init} = 1.75$

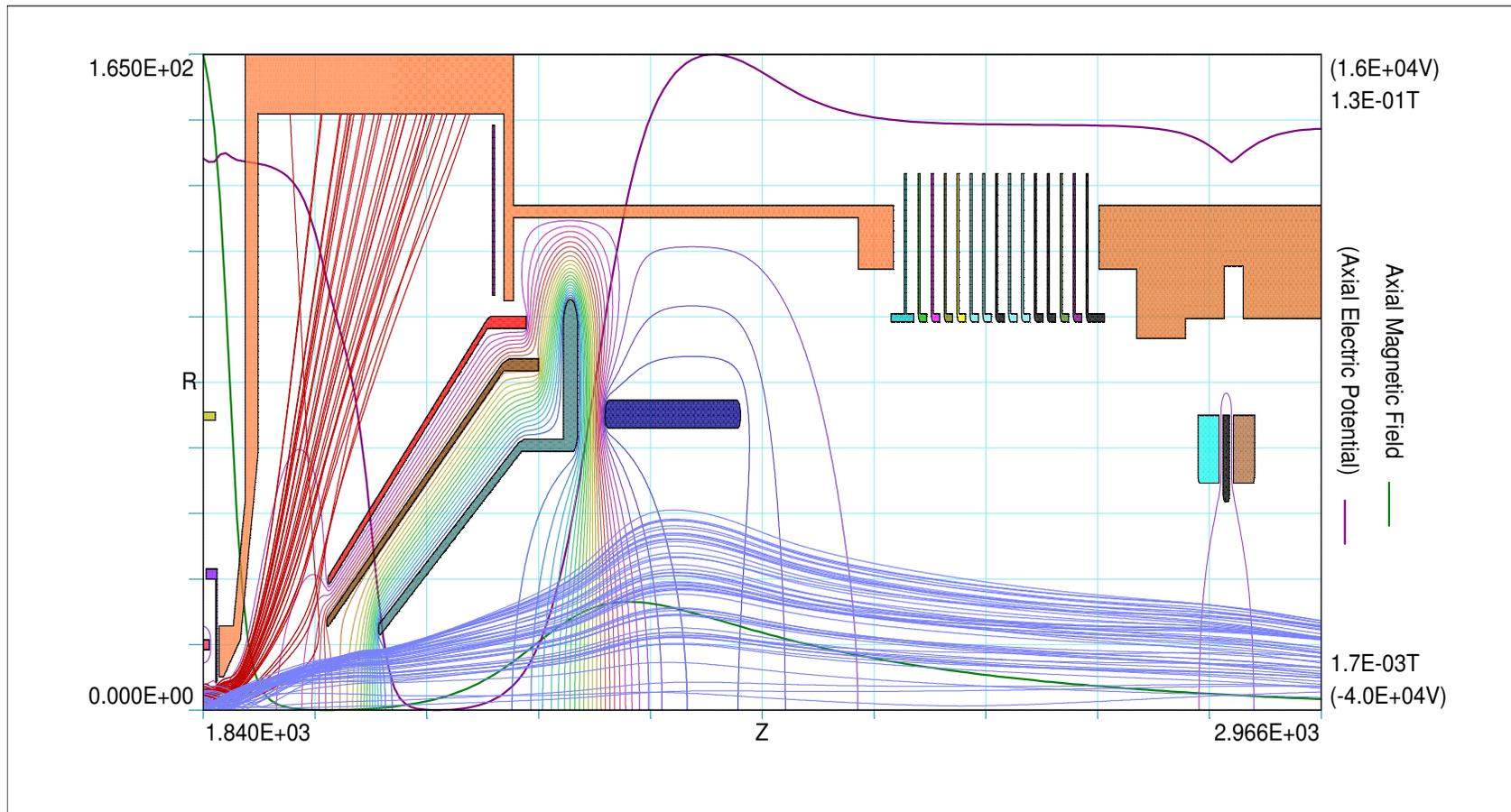


Fig. 14. $I_{ion} = 1.0 \text{ mA}$, $E_{ion} = 21.0 \text{ keV}$, $\epsilon_{unnorm} = 303.4 \text{ mm} \cdot \text{mrad}$, $\epsilon_{RMS_norm} = 0.0363 \text{ mm} \cdot \text{mrad}$.

This Plot Created On: June 11, 2008
at 11:35:28

EOU File: 1mA21K40K18K3K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 1mA21keV40k18k3k.TOU

$I_{el} = 10.0 \text{ A}$
 $U_{EC} = 10.0 \text{ kV}$
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0 \text{ kV}$
 $U_{ion_extr} = U_{cath} - 7.0 \text{ kV}$
 $U_{ion_lens} = -50.0 \text{ kV}$
 $U_{adaptor} = +8.0 \text{ kV}$
 $U_{grid} = -3.0 \text{ kV}$

Au1+, $I_{ion} = 1.0 \text{ mA}$
 $E_{ion} = 21.0 \text{ keV}$
 $Emit_{unnorm} = 303.0 \text{ mm} \cdot \text{mrad}$
 $Emit_{RMS_norm} = 0.036 \text{ mm} \cdot \text{mrad}$
 $R_{init} = 24 \text{ mm}$
 $Divergence_{init} = 40 \text{ mrad}$
 $Alfa_{init} = -2.8, \text{Beta}_{init} = 1.75$

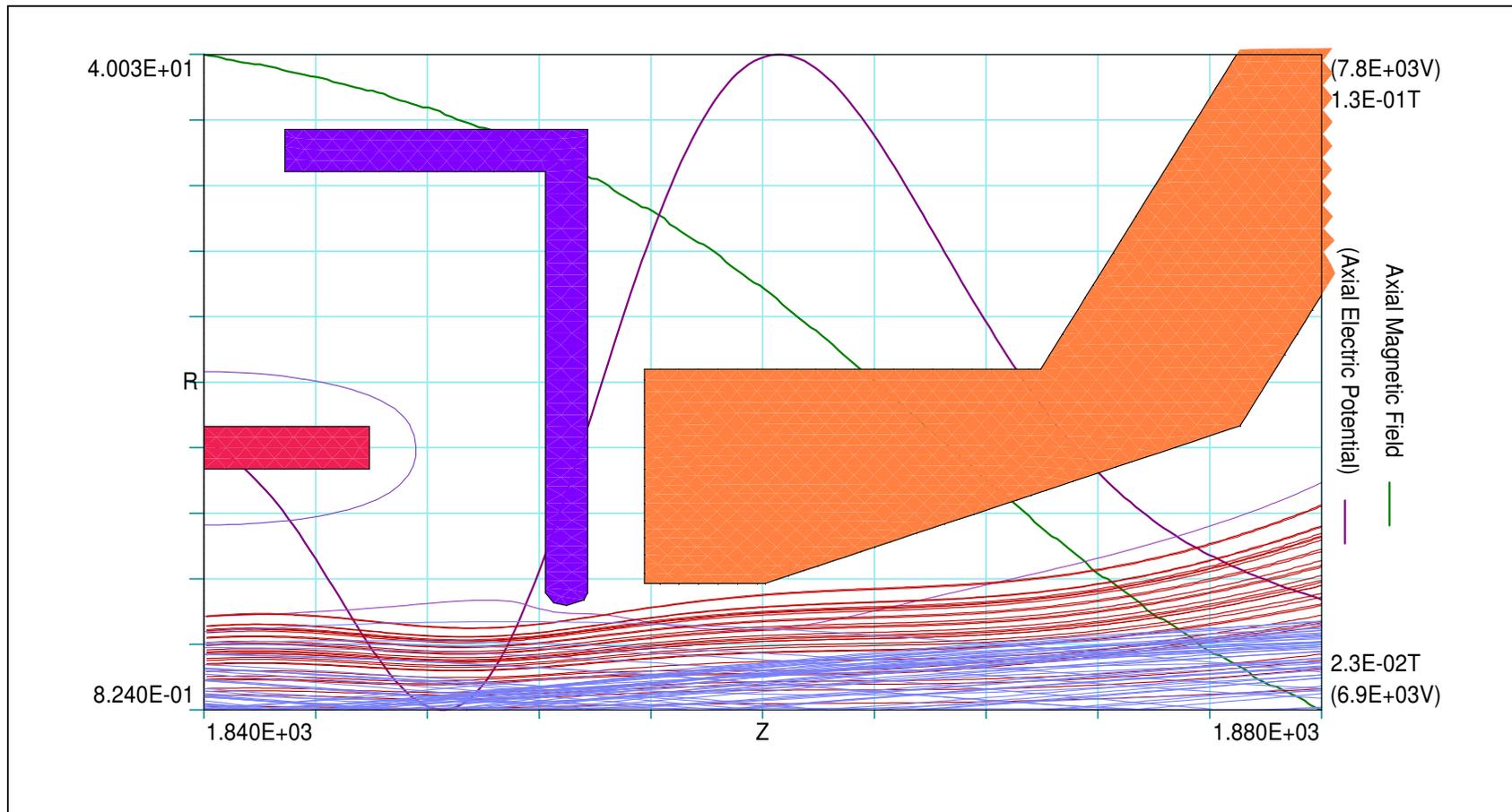


Fig. 15. $I_{ion} = 1.0 \text{ mA}$, $E_{ion} = 14.0 \text{ keV}$, $\epsilon_{unnorm} = 303.4 \text{ mm} \cdot \text{mrad}$, $\epsilon_{RMS_norm} = 0.0363 \text{ mm} \cdot \text{mrad}$, Zoom at the EC entrance with the same X and Y scale.

This Plot Created On: June 23, 2008
at 17:23:48

EOU File: FE1M14K38K17K6K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 1mA14keV38k17k6k.TOU

$I_{el} = 10.0$ A
 $U_{EC} = 10.0$ kV
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0$ kV
 $U_{ion\ extr} = U_{cath} - 7.0$ kV
 $U_{ion\ lens} = -48.0$ kV
 $U_{adaptor} = +7.0$ kV
 $U_{grid} = -6.0$ kV

Au1+, $I_{ion} = 1.0$ mA
 $E_{ion} = 14.0$ keV
 $Emit_{unnorm} = 303.0$ mm*mrad
 $Emit_{RMS_norm} = 0.036$ mm*mrad
 $R_{init} = 24$ mm
 $Divergence_{init} = 40$ mrad
 $Alfa_{init} = 2.8$, $Beta_{init} = 1.75$

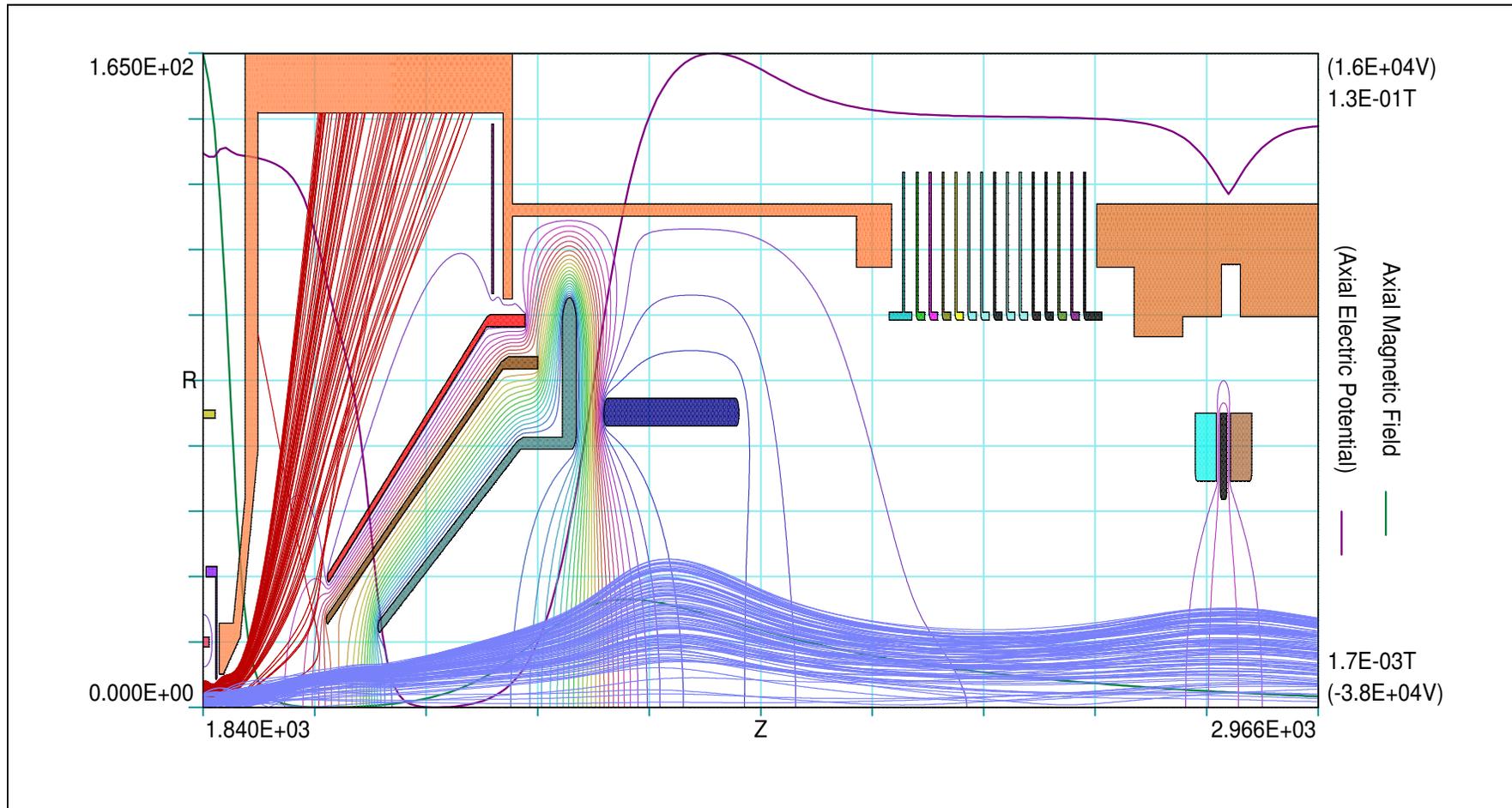


Fig. 16. $I_{ion} = 1.0$ mA, $E_{ion} = 14.0$ keV, $\epsilon_{unnorm} = 303.4$ mm*mrad, $\epsilon_{RMS_norm} = 0.0363$ mm*mrad.

This Plot Created On: June 23, 2008
at 17:23:48

EOU File: FE1M14K38K17K6K.EOU
BOU File: M32_16_1_69E5.BOU
TOU File: 1mA14keV38k17k6k.TOU

$I_{el} = 10.0$ A
 $U_{EC} = 10.0$ kV
 $U_{refl} = U_{EC}$
 $U_{repel} = U_{EC} + 1.0$ kV
 $U_{ion\ extr} = U_{cath} - 7.0$ kV
 $U_{ion\ lens} = -48.0$ kV
 $U_{adaptor} = +7.0$ kV
 $U_{grid} = -6.0$ kV

Au1+, $I_{ion} = 1.0$ mA
 $E_{ion} = 14.0$ keV
 $Emit_{unnorm} = 303.0$ mm*mrad
 $Emit_{RMS}_{norm} = 0.036$ mm*mrad
 $R_{init} = 24$ mm
 $Divergence_{init} = 40$ mrad
 $Alfa_{init} = 2.8$, $Beta_{init} = 1.75$

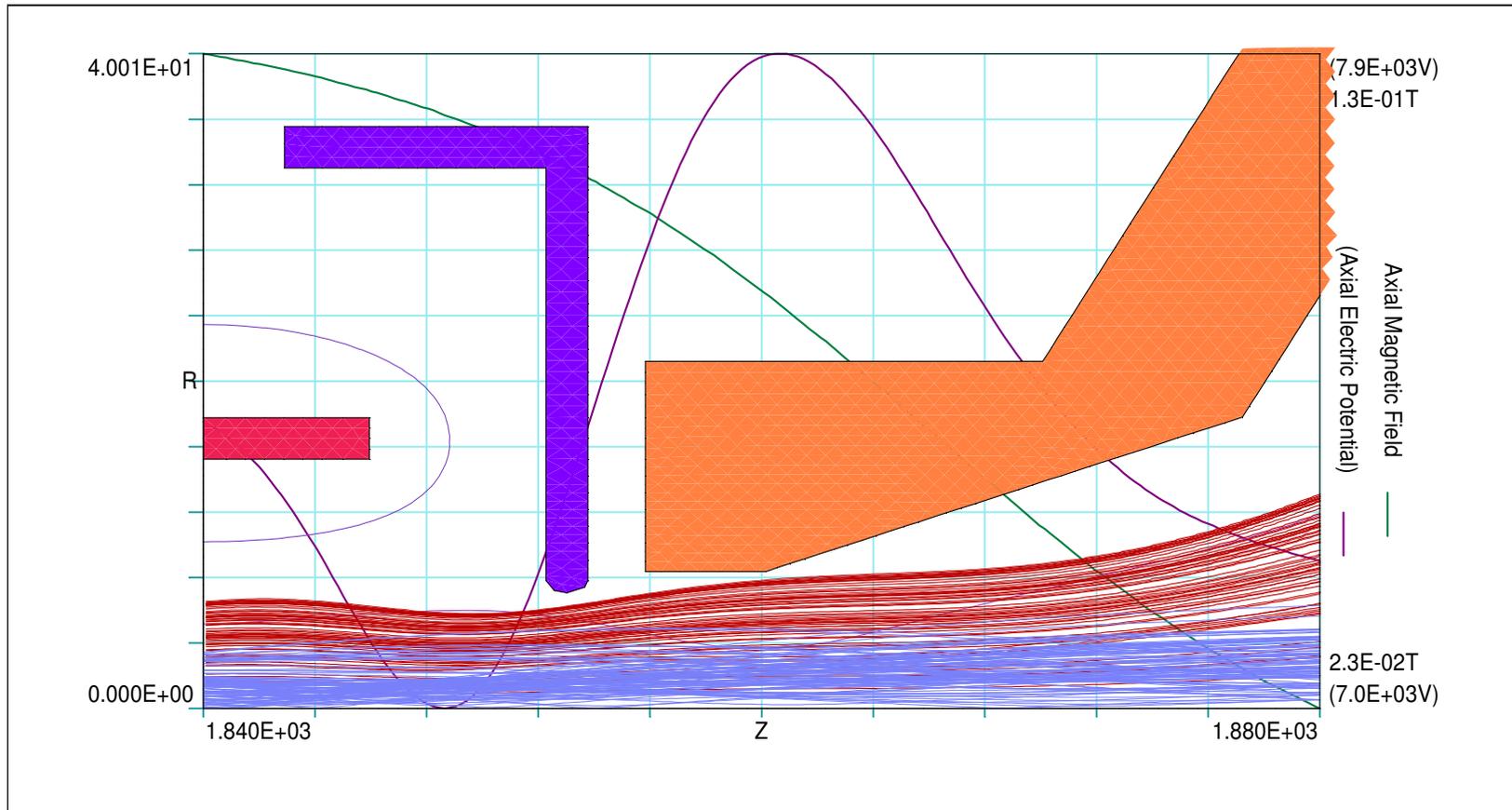


Fig. 17. $I_{ion}=1.0$ mA, $E_{ion}=14.0$ keV, $\epsilon_{unnorm}=303.4$ mm*mrad, $\epsilon_{RMS}_{norm}=0.0363$ mm*mrad, Zoom at the EC entrance with the same X and Y scale.